1. Background
The ESRC-funded programme of research was in the area of anxiety and cognitive performance. Although the research literature is somewhat inconsistent, there is evidence suggesting that negative effects of anxiety on processing and on performance may involve either state anxiety (current anxious experience) or trait anxiety (a personality reflecting vulnerability to anxiety). A number of different theoretical accounts have been offered to explain the various findings. However, the experiments carried out within the research programme were motivated by two theories of anxiety and performance: processing efficiency theory (Eysenck & Calvo, 1992), and our new attentional control theory (Eysenck et al., 2007).

Processing efficiency theory makes two major assumptions. The first such assumption involves a conceptual distinction between performance effectiveness (quality of performance) and processing efficiency (relationship between performance effectiveness and use of processing resources). It is assumed within the theory that anxiety typically impairs efficiency more than effectiveness, because anxious individuals attempt to compensate for poor performance by applying additional effort to the ongoing task. Second, it is assumed that the adverse effects of anxiety on processing efficiency occur mainly within the central executive component of the working memory system (Baddeley, 2002), a component that is involved in various higher-level attentional and other executive processes. There is reasonable empirical support for these two theoretical assumptions in the research literature.

Processing efficiency theory argues that anxiety affects the efficiency of the central executive. However, this is imprecise given that the central executive fulfills several functions (Miyake et al., 2000). Clarification on this issue was included within attentional control theory. According to this theory, anxiety adversely affects the efficiency of the inhibition and shifting functions identified by Miyake et al. (2000) in their latent-variable analysis based on many executive tasks. The inhibition function relates to inhibition of prepotent responses and distractors and the shifting function relates to shifting of mental set (e.g., in task switching). Past research had provided much support (although much of it is indirect) for the hypothesis that anxiety impairs the inhibition function but this support was rather indirect and failed to specify the processes involved.

There had been very little previous research relevant to the hypothesis that anxiety impairs the shifting function, and none of it was of direct relevance. For example, it has been found consistently that the negative effects of anxiety are greater when two demanding tasks are performed concurrently (dual-task conditions) than when the secondary task is undemanding (e.g., Eysenck, Payne, & Derakshan, 2005). If dual-task performance under demanding conditions involves rapid task switching, then such findings may reflect impaired efficiency of the shifting function in high-anxious individuals. However, this interpretation is equivocal given the absence of any direct manipulation of demands on the shifting function and the failure to assess attentional processes during task performance.

Finally, the assumption from processing efficiency theory that anxiety impairs processing efficiency more than performance effectiveness is also incorporated in attentional control theory, and was subjected to testing. In sum, the research
programme was designed to provide several rigorous tests of attentional control theory and to enhance our understanding of the ways in which anxiety affects.

2. Objectives
There were several aims and objectives of the research programme. However, all of the aims and objectives relate to testing the major predictions of attentional control theory. These aims and objectives will be discussed within the context of individual experiments or related series of experiments. However, one broad objective will be mentioned initially. Previous research had failed to clarify whether the adverse effects of anxiety on efficiency and performance were due more to individual differences in trait anxiety or in state anxiety. This issue is complicated by the fact that trait and state anxiety are typically moderately correlated with each other. In some of the initial experiments, participants were exposed to low versus high evaluative conditions in order to manipulate experimentally the level of state anxiety. However, these manipulations were relatively modest in order to ensure that the research was totally ethical, and so they did not influence efficiency or effectiveness.

First, a major objective was to provide a more direct test of the hypothesis that anxiety impairs the efficiency of the inhibition function than had been done before by using the anti-saccade task. In this task, a cue presented to one side of the fixation point is followed very shortly by a target on the opposite side of the fixation point. Participants are instructed to make a saccade only to the target and the latency of the first saccade in the correct direction provides a valid measure of the efficiency of the inhibition function. As a control condition, there is the pro-saccade task, in which the cue and target are on the same side of the fixation point, as a result of which the inhibition function is not needed. Efficiency and effectiveness were assessed: the latency of the first correct saccade was a measure of efficiency and the error rate in terms of incorrect saccades was a measure of effectiveness. It was envisaged in the grant proposal that there would be one experiment using the anti-saccade task. In fact, however, the anti-saccade task proved of great value as a way of assessing the inhibition function (Miyake et al., 2000, had identified it as an excellent task for that purpose), and it consistently produced significant findings supporting attentional control theory (see Results and Outputs sections). Accordingly, additional experiments using the anti-saccade task were conducted.

Second, another objective was to assess the effects of anxiety on inhibition of distracting positive and negative stimuli using a different paradigm and exploring the effects of manipulating working memory load and emotional valence of distracters. It was predicted that high-anxious individuals have reduced inhibition when the to-be-inhibited stimuli are threat-related rather than neutral. The key observation concerns the adverse effects of anxiety on cognitive performance. There is only indirect evidence available as performance impairment may reflect only partial attentional focus on the distracters (for example, findings from the Emotional Stroop task, in which the colours of threat-related words have to be named). We aimed to rectify limitations with previous research and test predictions from attentional control theory. The paradigm represented a considerable extension of the one used by Hopko et al. (1998), and involved self-paced reading of constructed texts in a within-participants’ design. Texts included threat-related and neutral distracters unrelated to the story. Eye-movements were recorded online to measure the pattern of eye-movements on distracters, Another aim was to test the effects of working memory load on inhibitory processes and its interaction with anxiety. According to attentional control theory, anxiety should impair the inhibition function to a greater extent when demands on
working memory increase. We predicted that anxiety would be associated with more fixations and longer dwell times on distracters and that this effect would be greater with threatening distracters, especially under high working memory load.

Third, another objective was to assess the effects of anxiety on dual-task performance by investigating attentional processes on primary and secondary tasks with more precision than in previous research. According to Easterbrook’s (1959) narrowing of attention hypothesis, anxiety should impair the performance of the secondary task presented in the periphery to a greater extent than the primary task presented in the centre of the visual field. In contrast, according to attentional control theory, anxiety should not affect performance on the secondary task if the primary task stimuli are not more salient (or attention-attracting) than those of the secondary task. We used a modified version of the paradigm used by Solso et al. (1968). There is a fixation point with small, medium, and large concentric circles around it. Stimuli (letters) are presented, distributed equally on the periphery of each of the circles. Half are salient and are in either of the circles. Salience of target was manipulated in a within-subject design according to the brightness of the stimuli. Participants were asked to detect the target. The primary task involved finding the target letter which could be on any of the three circles. Working memory load was manipulated in a between-participant design. We predicted that the effects of anxiety should depend on salience and instructions rather than distance from fixation, this should depend on salience of target and working memory load where the effects should be greater. Results provided some support for our theoretical predictions (see Results section).

Fourth, another major objective was to test the hypothesis that anxiety impairs the shifting function by providing a direct test of it. We used a task-switching paradigm in which two arithmetical tasks (e.g., multiplication and division) were either performed in separate blocks (non-switching condition) or on alternate trials (switching condition). In this paradigm, the processing demands of the tasks themselves are equated for the two conditions, meaning that the requirement to shift attention is the major difference between them. It was argued that negative effects of anxiety on the efficiency of the shifting function would be revealed by slower performance in the switching condition than in the non-switching condition. However, if the negative effects of anxiety were limited to efficiency rather than performance effectiveness, there should be no effects of anxiety on the error rate. In addition, cueing was manipulated: cues indicating the nature of the task were either present or absent on each trial on the assumption that explicit cueing would facilitate use of the shifting function. It was thus predicted that anxiety would have a more adverse effect on solution latencies in the no-cueing condition than in the cueing condition. The findings obtained from use of the task-switching paradigm consistently supported the predictions of attentional control theory (see Results and Outputs sections).

Fifth, another major objective was to test the prediction that anxiety impairs the shifting function under reasonably ecologically valid conditions by focusing on prospective memory. Prospective memory involves remembering to carry out an intended action in response to occasional cues while performing another task. Failures of task switching occur when participants do not respond to cues on the prospective-memory task or respond slowly to them. It was decided to extend exploration of the effects of anxiety on the shifting function to prospective memory because failures of prospective memory are an everyday occurrence and so the study of prospective memory has ecological validity. It was predicted from attentional control theory that high-anxious individuals should have worse prospective-memory performance than
low-anxious ones, especially when the task made high demands on the shifting function. The findings from both experiments supported the predictions of attentional control theory (see Results section).

Sixth, the objective of testing the prediction that anxiety impairs the shifting function was applied to a dual-task paradigm. As indicated above, previous research on anxiety using dual-task paradigms has failed to manipulate demands on attentional control in a direct way, and so the relevance of the findings to the prediction cannot be ascertained. We conducted an experiment involving single- and dual-task conditions. In order to test the prediction, there were two dual-task conditions that involved the same basic processing requirements. However, unpredictability about the relationship between stimulus and response positions in one dual-task condition produced increased demands on the shifting function. The experimental design met the objective of testing predictions of attentional control theory as applied to the shifting function. The findings provided some support for the theory (see Results section). However, the impact of the manipulation of demands on the shifting function across dual-task conditions was comparable for high-anxious and low-anxious groups, which was not as predicted. It is possible that the manipulation was insufficiently rigorous to produce the predicted findings.

3. Methods
All of the studies within the research programme involved the use of experimental paradigms. Most of the experimental paradigms used were modified from those previously used in ways designed to ensure that the major predictions were addressed. Much of the originality of the research programme was based on the novel application of paradigms to understanding the effects of anxiety on the cognitive system rather than the development of brand-new methods. However, an original feature of the methods included eye-movement recordings to capture moment-to-moment of attentional processing thus providing a more direct measure of the mechanisms underlying attentional control (for an excellent review see Weirich et al. (2008)). The use of the anti-saccade task proved of great value, but this task had hardly ever previously been used to assess the effects of anxiety on cognitive performance.

In similar fashion, there is a large literature on task switching, but no previous published anxiety research had used task-switching paradigms. However, such paradigms provide one of the most direct ways of testing major predictions from attentional control theory.

4. Results
Two experiments were carried out to investigate the predictions relating to the effects of anxiety on the inhibition function as assessed by the antisaccade paradigm. The first experiment assessed inhibitory processes when the to-be-inhibited stimulus was a neutral oval cue object. The second experiment used emotional facial expressions (angry, happy, and neutral) as cues to assess inhibition for negative and positive material. In both experiments blocks of anti- and pro-saccade trials were presented. In Exp 2, facial expressions (cues) were presented randomly within each anti- and pro-saccade block. In the antisaccade condition, participants were asked to NOT look at the cue but to look away to the mirror position of the cue as quickly as it appeared on the screen. In the prosaccade task, participants were instructed to simply look towards the cue. In this task there should be no effect of anxiety as there is no competition between stimulus-driven and top-down mechanisms of attentional control. The main
dependent variables of interest were correct antisaccade latencies and error rates. The key findings confirmed major predictions of attentional control theory. Anxiety affected correct antisaccade latencies as indexed by longer latencies in the high-anxious individuals; thus confirming the prediction that anxiety impaired processing efficiency. Anxiety had no effect on antisaccade error rates; confirming the prediction that anxiety did not affect performance effectiveness. When emotional cues were used as stimuli anxiety affected correct antisaccade latencies in response to angry facial expressions compared to happy and neutral facial expressions, thus confirming the prediction that anxiety impairs inhibition in the presence of threat-related stimuli such as angry faces. There were no effects of anxiety on error rates suggesting that performance effectiveness was not influenced. In neither experiment did anxiety affect performance on the prosaccade task. These two experiments provided direct evidence that anxiety impaired processing efficiency via its adverse effects on the inhibition function of the central executive component of working memory, and these two experiments are reported in a press journal article.

One experiment tested the effects of anxiety on the efficient inhibition of distracters using a reading task. In this experiment eye-movements were recorded online during self-paced reading of the stories. Participants read ‘neutral’ stories that included neutral and threat-related distractor words unrelated to the story. They completed a comprehension task when they had finished reading the story. Working memory load was manipulated in a between-subject design where participants were told that their comprehension ability will be evaluated by others. Consistent with predictions of attentional control theory, results on reading time showed that high-anxious individuals took longest to read the stories in the presence of both neutral and threat-related static distracters. However, there was no interaction with distracter valence, probably due to the fact that neutral distracters were difficult to identify from the stories that also conveyed neutral material, whereas threat related words stood out. Eye-movement data showed that high-anxious individuals compared with low-anxious individuals made more fixations when stories contained distracters and ‘dwell time’ increased under high working memory load. These findings are as predicted by attentional control theory. They suggest that anxiety reduces the efficiency of the inhibition function of working memory, and that this effect is greater when more attentional resources are needed for effective task performance.

One experiment challenged Easterbrook’s (1959) theory of narrowing of attention in anxiety. Participants searched for ‘salient’ and ‘non-salient’ targets and eye-movements were recorded to assess distance and number of fixations on inner and outer circles from the central fixation point. According to attentional control theory, the effects of anxiety on performance should depend on stimulus salience and instructions rather than distance from fixation and this effect should be greater under high working memory load. Our results indicated that while salience of target did not interact with anxiety; the effects of distance from fixation and working memory load did. High-anxious individuals did not take longer to identify targets as a function of distance from central fixation point. However, the high-anxious individuals took longer than the low-anxious individuals under high working memory load to identify the target when targets were presented on the inner circle. The greater impact of high working memory load on high-anxious than of low-anxious individuals is as predicted by attentional control theory, but the non-significant interaction between target salience and anxiety on speed of target detection is not for reasons that remain unclear.
One experiment was carried out to investigate predictions relating to the effects of anxiety on the shifting function as assessed by a task-switching paradigm. Participants performed two arithmetical tasks (multiplication and division; addition or subtraction) in switching or non-switching conditions and with explicit cues indicating the required arithmetical function present or absent. There were three key findings, all of which were predicted on the basis of attentional control theory. First, the adverse effects of anxiety centred on efficiency (based on solution latencies) rather than on performance effectiveness (based on error rates). Second, there was a highly significant interaction between anxiety and task switching: in this interaction, the negative effects of anxiety on solution latencies were much greater in the task-switching condition than in the non-task-switching condition. This crucial interaction provides strong support for the hypothesis that anxiety impairs the efficiency of the shifting function. Third, there was a highly significant interaction between anxiety and cueing (present vs. absent): in this interaction, the negative effects of anxiety on solution latencies were much greater when cueing was absent than when it was present. This interaction was predicted theoretically on the basis that use of the shifting function is more difficult when cues are absent than when they are present. Thus, there was strong empirical support for all of the main predictions based on attentional control theory.

Two experiments were conducted to investigate predictions relating to the effects of anxiety on the shifting function as applied to prospective memory. The overarching hypothesis in both experiments was that adverse effects of anxiety on prospective memory performance would be greater when detection of prospective memory targets makes more demands on attentional control than when it makes fewer demands. In the first experiment, targets were either well-defined (specific words) or not well-defined (category members). The performance of the high-anxious participants was only significantly worse than that of the low-anxious ones in the more difficult latter condition. In the second experiment, targets were either cued in advance or not cued in advance on the assumption that cueing reduces the demands on attentional control. As predicted, high-anxious participants performed significantly worse than low-anxious ones only in the absence of cueing. Thus, the central prediction was supported in both experiments in spite of a major difference in the manipulation of demands on attentional control in each experiment. This provides evidence that there is some generality to the findings.

One experiment was carried out to test the hypothesis that anxiety impairs the efficiency of the shifting function by using a dual-task paradigm. Participants performed simple tasks under single-task and dual-task conditions, and there were dual-task conditions varying in terms of the demands on the shifting function based on manipulating stimulus-response predictability. There was a highly significant interaction between anxiety and task conditions: in this interaction the high-anxious group performed worse than the low-anxious group under dual-task conditions but there was a non-significant difference between the two groups under single-task conditions. Performance was significantly worse when dual-task conditions imposed more demands on the shifting function. However, this manipulation did not interact with anxiety, perhaps because it was insufficiently rigorous.

5. Activities
Michael Eysenck has presented findings from the ESRC research programme at several international conferences and at various universities in the United Kingdom and abroad, including Bath University, Kent University, Bournemouth University,
Roehampton University, Queen’s University Belfast, Hertfordshire University, Birkbeck University of London, Maynooth University, Ireland, Warsaw School of Social Sciences and Humanities, and the Faculty of Psychology at Sopot, Poland. Nazanin Derakshan has presented findings from the ESRC research programme as invited talks at national as well as international universities including: Essex University, Dundee University, The British Neurophysiological Society (UCL), Manchester University, Bristol University (Nov. 2008); Reading University (Nov. 2008), Roehampton University, Ghent University (Belgium), Kent University. The international conferences at which ESRC-funded research findings were reported include the following: (1) Stress and Anxiety Research Society annual meeting in the Dominican Republic, July 2007; (2) Stress and Anxiety Research Society annual meeting in London, July 2008; (3) International Conference on Emotion in Haifa, Israel, June 2008; (4) International Conference on Emotion in Cluj, Romania, June 2008; (5) International Stress and Anxiety Conference, Benidorm, September 2006; (6) International Conference on Emotion and Personality, Cracow, September 2006; and (7) Second Biennial Symposium on Personality and Social Psychology, Cognition, and Emotion, Warsaw, September 2008, (8) World Congress of Cognitive and Behavioural Therapy, Barcelona, Spain, July 2007, (9) Society for Psychophysiological Research, Vancouver, Canada, 2006, (10) Society for Psychophysiological Research, Savannah, USA, October 2007 (11). Society for Psychophysiological Research, Austin, Texas, October 2008. (12). Conference on the Development of Anxiety in Children: Neuroscience and Intervention; Herzliya, Israel, May 2009.

6. Outputs
Several outputs have already been accomplished, and several more are in preparation. First, a two-experiment article is in press. The details for this article are as follows: N. Derakshan, T.L. Ansari, M. Hansard, L. Shoker, & M.W. Eysenck (2009). Anxiety, inhibition, efficiency, and effectiveness: An investigation using the antisaccade task. *Experimental Psychology*. As the title indicates, the article focuses on the inhibition function and the two experiments produced clear evidence that anxiety impairs the efficiency of that function. Second, a theoretical article is in press. The details for this article are as follows: N. Derakshan & M.W. Eysenck (in press) Anxiety and performance: Processing efficiency and attentional control. *European Psychologist*. This article both extends attentional control theory (Eysenck et al., 2007) and reports succinctly many of the main findings emerging from the ESRC grant across several experiments. Third, an article on task switching has been submitted for publication. The details are as follows: N. Derakshan, S. Smyth, & M.W. Eysenck, Effects of state anxiety on performance using a task-switching paradigm: An investigation of attentional control theory. Cognition.

7. Impacts
There is strong evidence that attentional control theory and the ESRC-funded empirical research testing the theory are having an impact. For example, at the Stress and Anxiety Research Society meeting in London in July 2008, several researchers reported research based on this theoretical approach. In addition, there is ongoing research in various psychology departments in the United Kingdom and other countries that has been influenced by the research results obtained by us during the research programme. Given the promising line of results that this grant has generated the need to extend this work to understand the underlying mechanisms of attentional
control in depression is becoming increasingly important. There is substantial
evidence to suggest that anxiety and depression correlate but very little has aimed to
elucidate the independent processes contributing to the development of each disorder.
Inspired by the current output and its international impact in the field, the Royal
Society is currently funding Dr Derakshan to investigate the neurocognitive
mechanisms of attentional control in depression. This work is being carried out in
collaboration with the department of psychology at Ghent University (that has an
excellent reputation in cognitive affective neuroscience research). It is hoped that this
collaboration will provide the necessary steps for developing a theoretical account of
attentional control in depression.

Attentional control theory has been put to good use in the area of cognitive
development in order to identify children who are at risk for developing anxiety
disorders. The cognitive developmental group at the University of Cluj in Romania,
are using the attentional control theory to examine the impact of anxiety on cognitive
development and working memory, and in particular attentional control in pre-school
and primary school children. New publications in top APA journals are arising from
this lab as well as a forthcoming collaboration with the Affective and Cognitive
Neuroscience lab at Birkbeck.

There are clear educational implications of the research programme. We have found
consistently that anxiety impairs the efficiency of attentional control mechanisms in
terms of the inhibition and shifting functions. As a consequence, there are solid
reasons for assuming that interventions within education designed to reduce the
negative effects of anxiety on attentional control would enhance the academic
performance of anxious students.

8. Future Research priorities
The ESRC-funded research programme has successfully demonstrated that anxiety
impairs the efficiency of the inhibition and shifting functions using a variety of
different experimental paradigms. One research priority for the future is to investigate
the extent to which common processes are associated with these two functions. This
could be done by carrying out research in which there are four conditions involving
all combinations of low and high demands on the inhibition and shifting functions. If
there are commonalities between the two functions, we would anticipate that anxiety
would especially impair processing efficiency when the demands on the inhibition
and shifting functions were both high. Another priority (but one that would take some
time in preparation) is to develop effective attentional training techniques (especially
in children) to reduce or eliminate the adverse effects of anxiety on attentional
processes.

9. References


